

SiC POWER DEVICES

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for a greener tomorrow

Eco Changes is the Mitsubishi Electric Group's environmental statement, and expresses the Group's stance on environmental management. Through a wide range of businesses, we are helping contribute to the realization of a sustainable society.



MITSUBISHI ELECTRIC CORPORATION

HEAD OFFICE: TOKYO BLDG., 2-7-3, MARUNOUCHI, CHIYODA-KU, TOKYO 100-8310, JAPAN
www.MitsubishiElectric.com

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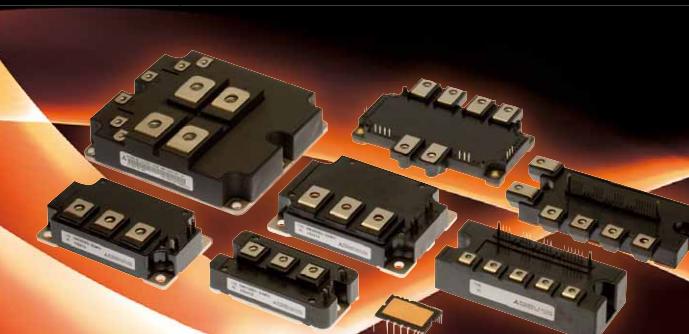


Innovative Power Devices for a Sustainable Future

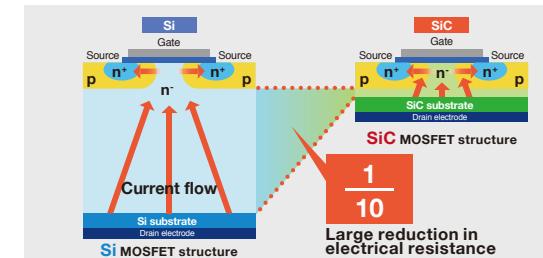
Traction, industrial equipment, building facilities, electric vehicles, renewable energies, home appliances...

Power devices are a key component in power electronics products for contributing to the realization of a low-carbon society. Attracting attention as the most energy-efficient power device is one made using new material, silicon-carbide (SiC). The material characteristics of SiC have led to a dramatic reduction in power loss and significant energy savings for power electronics devices. Mitsubishi Electric began the development of elemental SiC technologies in the early 1990s and has since introduced them to achieve practical energy-saving effects for products manufactured using SiC. Innovative SiC power modules are contributing to the realization of a low-carbon society and more affluent lifestyles.

*SiC: Silicon Carbide-Compound that fuses silicon and carbon at a ratio of one-to-one.

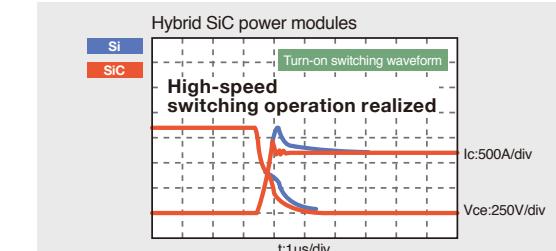


SiC with superior characteristics



Power loss reduced

SiC has approximately 10 times the critical breakdown strength of silicon. Furthermore, the drift layer that is a main cause of electrical resistance is one-tenth of the thickness. This allows a large reduction in electrical resistance and, in turn, reduces power loss. This SiC characteristic enables dramatic reductions in conductivity loss and switching loss in power devices.



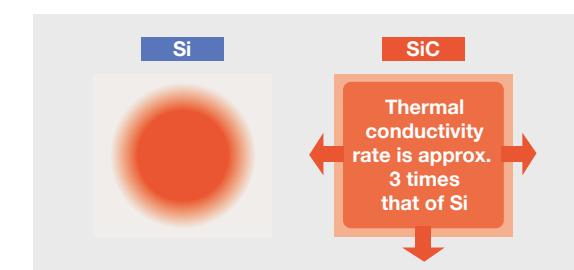
High-speed switching operation

With SiC, owing to the high dielectric breakdown, power loss is reduced and high-voltage is easier to achieve, it is possible to use Schottky Barrier Diodes (SBDs), which cannot be used with Si. SBDs can realize high-speed switching motion because they don't have accumulation carriers. As a result, high-speed switching can be realized.



High-temperature operation

When the temperature increases, electrons are excited to the conduction band and the leakage current increases. At times, this results in abnormal operation. However, SiC has three times the band gap width of silicon, preventing the flow of leakage current and enabling operation at high temperatures.



Heat dissipation

SiC has three times the heat conductivity of silicon, which improves heat dissipation.

SiC power modules appropriated by application

Application	Product name	Model	Rating		Connection	States	Insert pages		
			Voltages[V]	Current[A]					
Home appliances Industrial equipment	SiC-SBD	BD20060T	600	20	-	Commercially available	P3		
		BD20060S				Sample available			
		BD20060A				-			
		BD10120S	1200	10	-	Under development			
		BD20120S		20	-				
		BD20120SJ			-				
Industrial equipment	Hybrid SiC-IPM	PMH200CS1D060	600	200	6 in 1	Commercially available	P4		
		PMH75CL1A120		1200	75	6 in 1			
		PMF75CL1A120			4 in 1				
	Full SiC Power Modules	FMF400BX-24A	1200	400	2 in 1	Sample available	P5		
		FMF800DX-24A		800					
		FMF600DX2-24A		600					
Traction	Hybrid SiC Power Modules for High-frequency Switching Applications	FMF800DX2-24A		800		Under development	P6		
		CMH100DY-24NFH	1200	100	2 in 1				
		CMH150DY-24NFH		150					
		CMH200DU-24NFH		200					
		CMH300DU-24NFH		300					
		CMH400DU-24NFH		400					
		CMH600DU-24NFH		600					
Home appliances	Large Hybrid SiC DIPIPM™ for PV Application	PSH50YA2A6	600	50	4 in 1	Commercially available	P7		
		CMH1200DC-34S		1200	2 in 1				
		PSF15S92F6	600	15	6 in 1				
		PSF25S92F6		25					
Home appliances	Super-mini Hybrid SiC DIPPFC™	PSH20L91A6-A	20Arms	Interleaved					
		PSF20L91A6-A							

Terminology

- SiC Silicon Carbide
- IPM Intelligent Power Module
- DIPIPM™ Dual-In-Line Package Intelligent Power Module
- DIPPFC™ Dual-In-Line Package Power Factor Correction
- SBD Schottky Barrier Diode
- MOSFET Metal Oxide Semiconductor Field Effect Transistor
- IGBT Insulated Gate Bipolar Transistor
- Tr Transistor
- FW-SW Freewheeling switching loss

- FW-DC Freewheeling DC loss
- Tr-SW Transistor switching loss
- Tr-DC Transistor DC loss
- IGBT-SW IGBT switching loss
- IGBT-DC IGBT DC loss
- PV Photovoltaics
- CSTBT™ Mitsubishi Electric's unique IGBT that makes use of the carrier cumulative effect
- JBS Junction Barrier Schottky



600V/20A SiC-SBD for power supply systems
BD20060T Commercially available /BD20060S /BD20060A
/BD10120S/BD20120S/BD20120SJ **Under development**

Contribute to reducing power loss and the size of power supply systems

■ Features

- Power loss is reduced by approx. 21% compared to silicon (Si) products, contributing to energy conversion.
- The SiC-SBD allows high frequency switching and contributes to downsizing the reactor, heat sink and other peripheral components
- JBS structure allows high forward surge capability and contributes to improving reliability

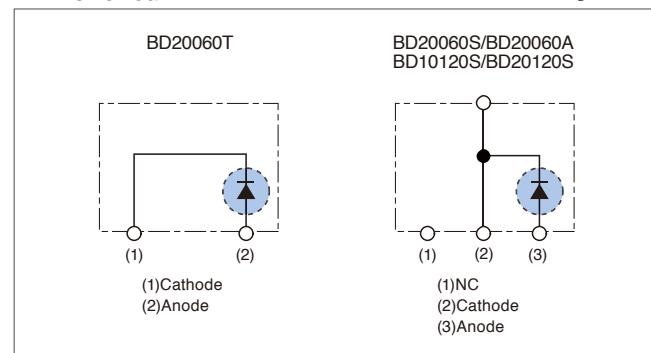
■ Product lineup

Model	Rated voltage	Rated current	Package
BD20060T	600V	20A	TO-220-2L
BD20060S**			TO-247-3L
BD20060A**			TO-263S-3L
BD10120S**		10A	
BD20120S**	1200V	20A	TO-247-3L
BD20120SJ**			

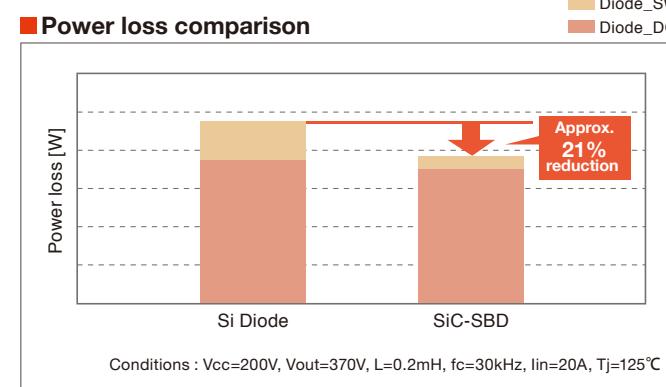


★ Under development

■ Inner circuit



■ Power loss comparison



Diode_SW
Diode_DC



1200V/75A Hybrid/Full SiC-IPM for Industrial Equipment
PMH75CL1A120/PMF75CL1A120 Sample available

Built-in drive circuit and protection functions realize high functionality

■ Features

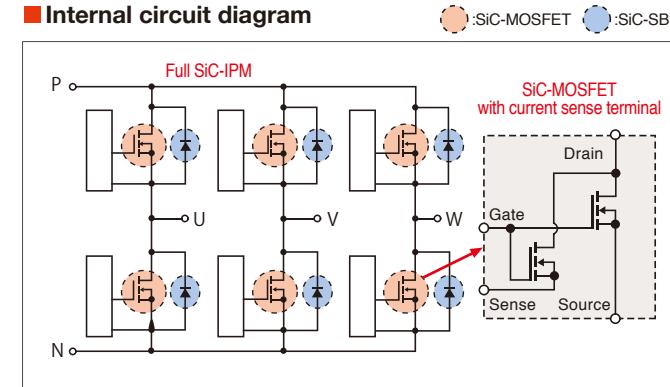
- Incorporates SiC-MOSFET with current sensor and built-in drive circuit and protection functions to deliver high functionality
- Significant reduction in power loss compared to the conventional product*
- Package compatible with the conventional product*

■ Main specifications

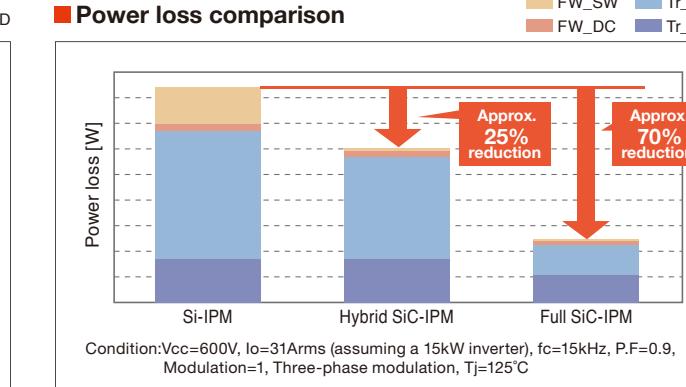
Rating	1200V/75A 6in1
Mounted Functions	<ul style="list-style-type: none"> Built-in drive circuit Under-voltage protection Short-circuit protection Over-temperature protection (Monitoring IGBT chip surface)



■ Internal circuit diagram



■ Power loss comparison



FW_SW Tr_SW
FW_DC Tr_DC



600V/200A Hybrid SiC-IPM for Industrial Equipment
PMH200CS1D060 Commercially available

SiC-SBD incorporated in an IPM with a built-in drive circuit and protection functions

Power loss reduction of approx. 20% contributes to enhancing the performance of industrial machinery

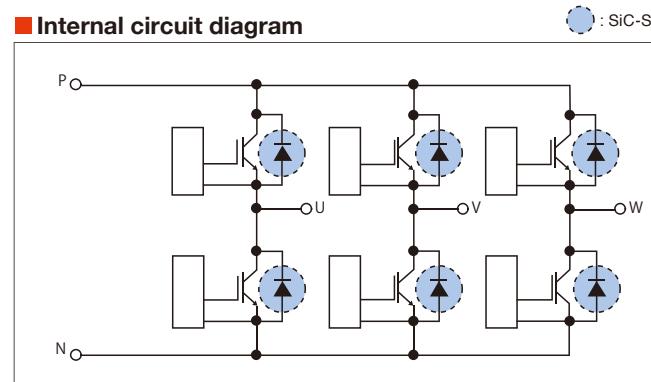
■ Features

- Hybrid combination of SiC-SBD and IGBT with current and temperature sensors implemented for IPM supplies high functionality and low loss enabling high torque and motor speed
- Recovery loss (Err) reduced by 95% compared to the conventional product*
- Package compatible with the conventional product* making replacement possible

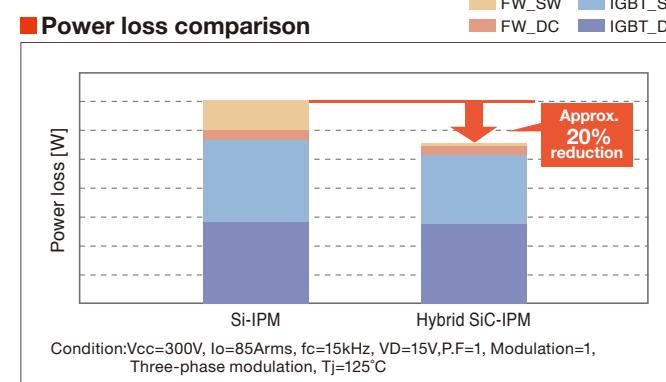
* Conventional product: Mitsubishi Electric S1 Series PM200SC1D060



■ Internal circuit diagram



■ Power loss comparison



FW_SW IGBT_SW
FW_DC IGBT_DC



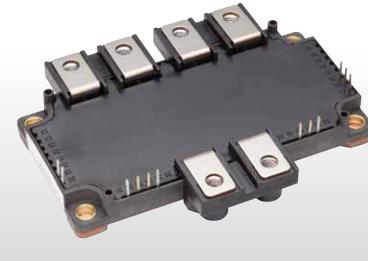
1200V/400A · 1200V/800A Full SiC Power Modules for Industrial Equipment
FMF400BX-24A/FMF800DX-24A Commercially available

Contributes to reducing size/weight of industrial-use inverters with the mounting area reduced by approx. 60%

■ Features

- Power loss reduced approx. 70% compared to the conventional product*
- Low-inductance package adopted to deliver full SiC performance
- Contributes to realizing smaller/lighter inverter equipment by significantly reducing the package size and realizing a mounting area approx. 60% smaller compared to the conventional product*

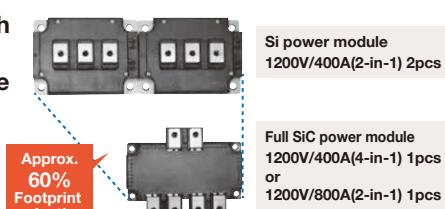
* Conventional product: Mitsubishi Electric CM400DY-24NF (1200V/400A 2in1) 2pcs



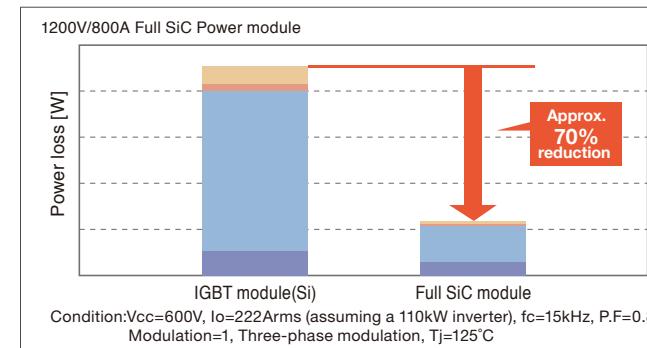
■ Product lineup

Applications	Rated voltage	Rated current	Circuit configuration	Package size (D xW)
Industrial equipment	1200V	400A	4-in-1	92.3 x 121.7mm
		800A	2-in-1	

■ Comparison with conventional product package



■ Power loss comparison



FW_SW Tr_SW
FW_DC Tr_DC



1200V/600A • 1200V/800A Full SiC Power Modules for Industrial Equipment FMF600DX2-24A/FMF800DX2-24A Under development

Contributes to enhancing the performance of industrial-use inverters thanks to built-in protection function for short circuit

■ Features

- By using short circuit monitoring circuit in the module it is possible to transfer a short circuit detection signal to the system side
- Power loss reduced approx. 70% compared to the conventional product*
- Low-inductance package adopted to deliver full SiC performance

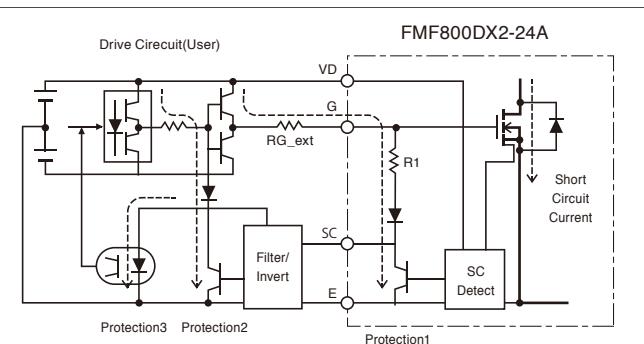
■ Product lineup

Model	Rated voltage	Rated current	External size (D x W)
FMF600DX2-24A**	1200V	600A	79.6 x 122mm
FMF800DX2-24A**	1200V	800A	

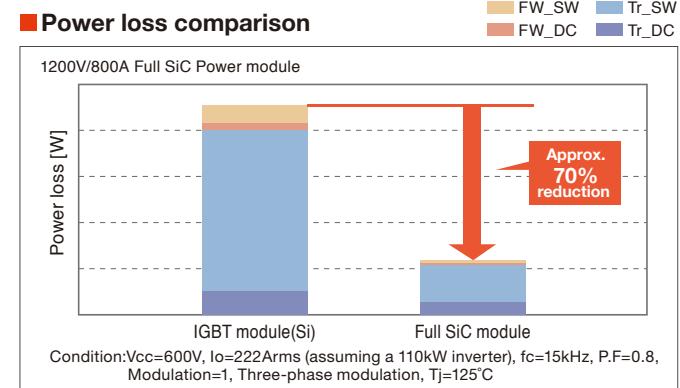


* Conventional product: Mitsubishi Electric CM400DY-24NF (1200V/400A 2in1) 2pcs

■ Protection circuit diagram



■ Power loss comparison



FW_SW

Tr_SW

FW_DC

Tr_DC



1700V/1200A Hybrid SiC Power Modules for Traction Inverters CMH1200DC-34S Commercially available

High-power/low-loss/highly reliable modules appropriate for use in traction inverters

■ Features

- Power loss reduced approximately 30% compared to the conventional product*
- Highly reliable design appropriate for use in traction
- Package compatible with the conventional product*

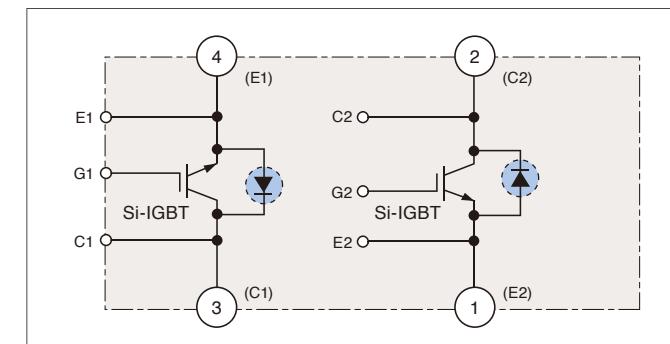
■ Main specifications

Module	Max.operating temperature	150°C
	Isolation voltage	4000Vrms
Si-IGBT @150°C	Collector-emitter saturation voltage	2.3V
	Switching loss 850V/1200V	turn-on 140mJ turn-off 390mJ
SiC-SBD @150°C	Emitter-collector voltage	2.3V
	Capacitive charge	9.0μC

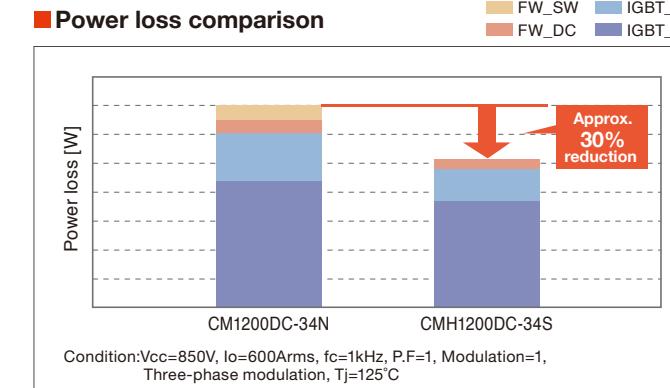


* Conventional product: Mitsubishi Electric Power Module CM1200DC-34N

■ Internal circuit diagram



■ Power loss comparison



Hybrid SiC Power Modules for High-frequency Switching Applications Commercially available

For optimal operation of power electronics devices that conduct high-frequency switching

■ Features

- Power loss reduction of approx. 40% contributes to higher efficiency, smaller size and weight reduction of total system
- Suppresses surge voltage by reducing internal inductance
- Package compatible with the conventional product*

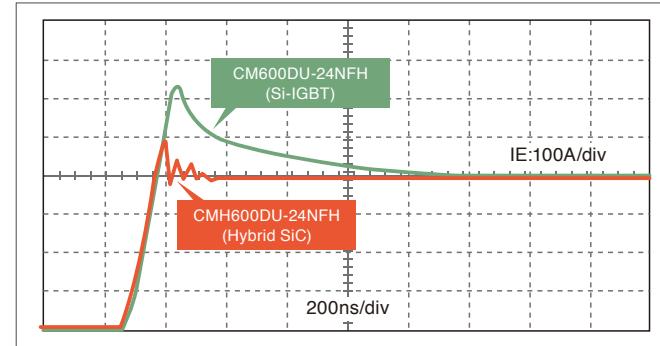
* Conventional product: Mitsubishi Electric NFH Series IGBT Modules

■ Product lineup

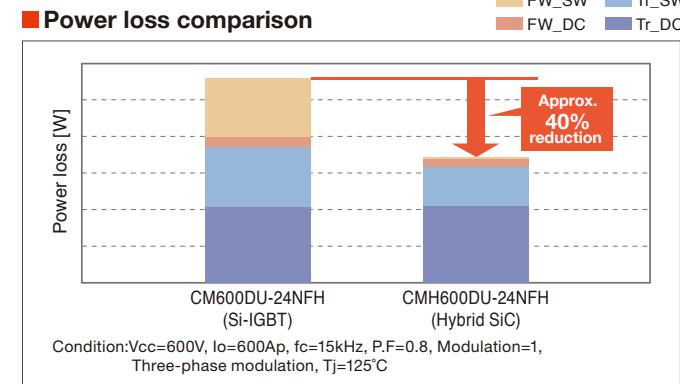
Applications	Model	Rated voltage	Rated current	Circuit configuration	External size (D x W)
Industrial equipment	CMH100DY-24NFH	1200V	100A	2-in-1	48 x 94mm
	CMH150DY-24NFH		150A		48 x 94mm
	CMH200DU-24NFH		200A		62 x 108mm
	CMH300DU-24NFH		300A		62 x 108mm
	CMH400DU-24NFH		400A		80 x 110mm
	CMH600DU-24NFH		600A		80 x 110mm



■ Recovery waveform (FWD)



■ Power loss comparison



FW_SW

Tr_SW

FW_DC

Tr_DC



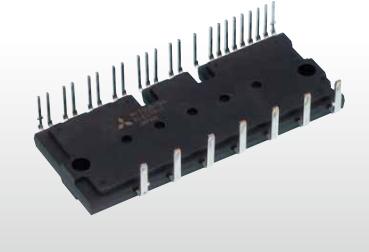
600V/50A Large Hybrid SiC DIPIPM™ for PV Applications PSH50YA2A6 Commercially available

More efficient power modules for PV power conditioner applications

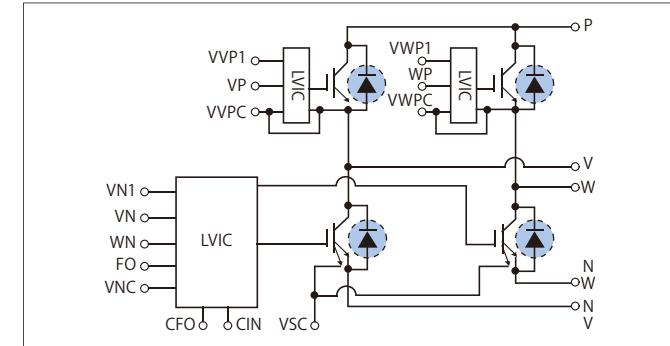
■ Features

- Hybrid structure achieved with SiC Schottky barrier diode and 7th-generation IGBT chips
- Power loss reduction of approx. 25% compared to the conventional product*
- Helps downsize PV inverter system thanks to modified short-circuit protection scheme

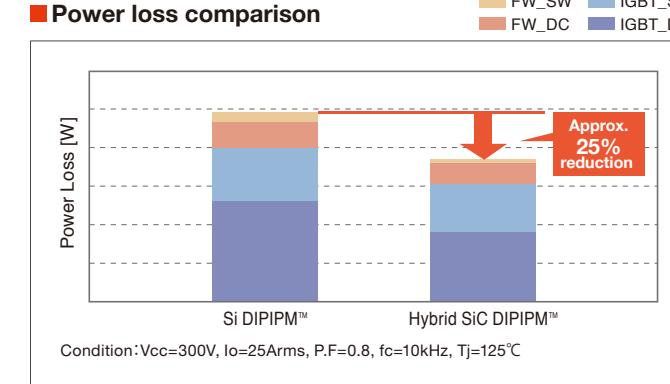
* Conventional product: Mitsubishi Electric Large DIPIPM™ PS61A99



■ Internal circuit diagram



■ Power loss comparison





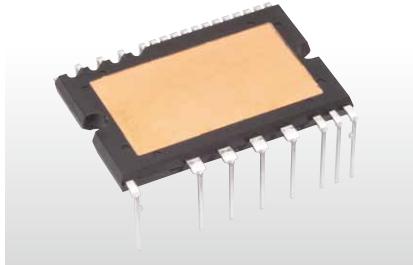
15A/25A Super-mini Full SiC DIPIPM™ for Home Appliances PSF15S92F6-A/PSF25S92F6-A Commercially available

Contributes to extremely high power-efficiency in air conditioners, and easily applicable to industrial equipment

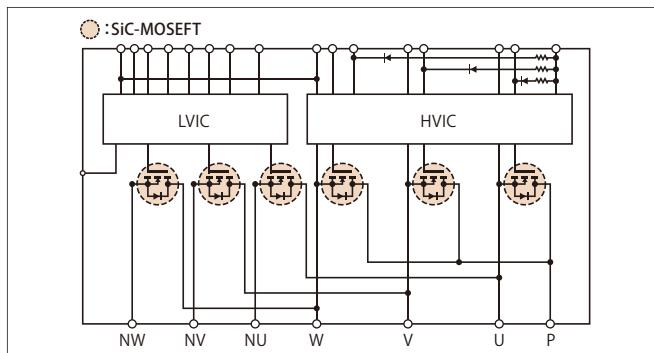
Features

- SiC-MOSFET achieves reduction in ON resistance, power loss reduced approx. 70% compared to conventional product*
- Construct low-noise system by reducing recovery current
- Numerous built-in functions: Bootstrap diode for power supply to drive P-side, temperature information output, etc.
- Unnecessary minus-bias gate drive circuit using original high V_{th} SiC-MOSFET technology
- As package and pin layout compatibility with conventional products* is ensured, simply replace with this product to improve performance

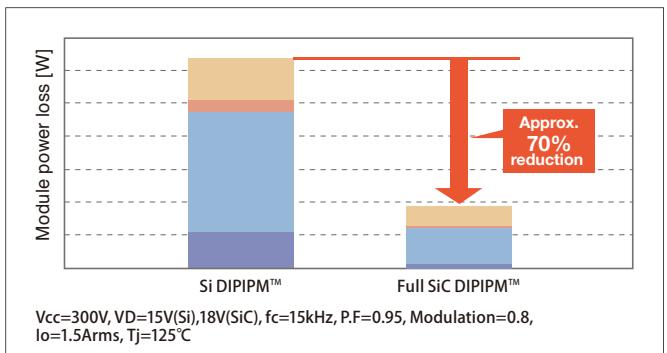
*Conventional product: Mitsubishi Electric Super-mini DIPIPM™ Series



Internal block diagram

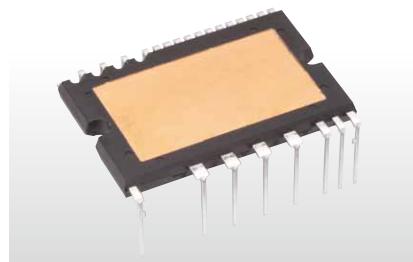


Power loss comparison



Super-mini Hybrid / Full SiC DIPPFC™ for Home Appliances PSH20L91A6-A / PSF20L91A6-A Commercially available

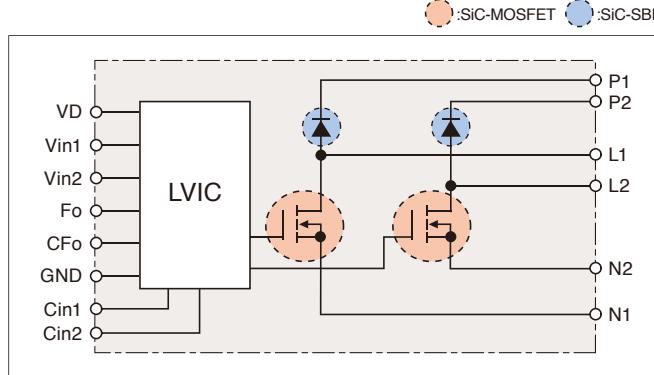
Utilizing SiC enables high-frequency switching and contributes to reducing the size of peripheral components



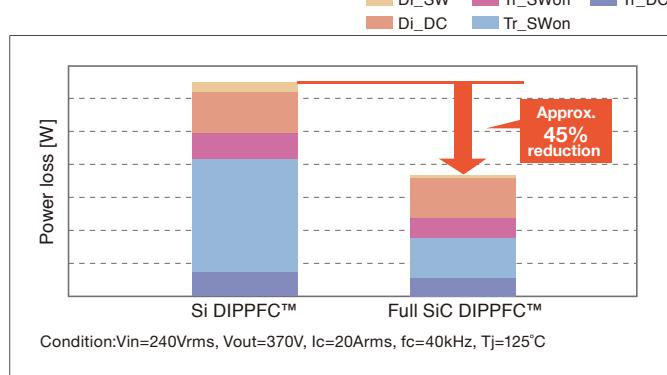
Features

- Incorporating SiC chip in the Super-mini package widely used in home appliances
- The SiC chip allows high-frequency switching (up to 40kHz) and contributes to downsizing the reactor, heat sink and other peripheral components
- Adopts the same package as the Super mini DIPIPM™ to eliminate the need for a spacer between the inverter and heat sink, and to facilitate its implementation

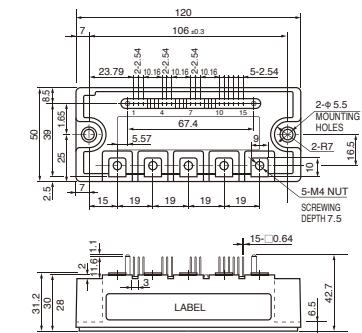
Internal block diagram (Full SiC DIPPFC™)



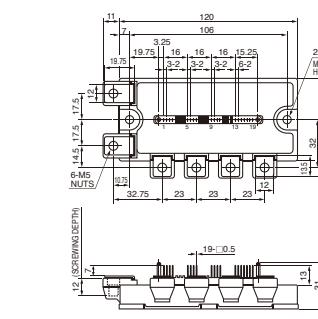
Power loss comparison



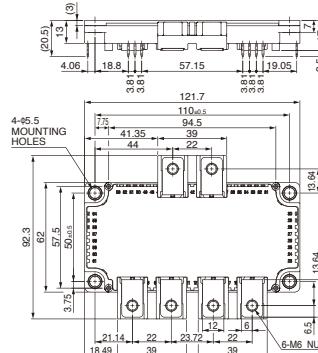
600V/200A Hybrid SiC-IPM for Industrial Use PMH200CS1D060



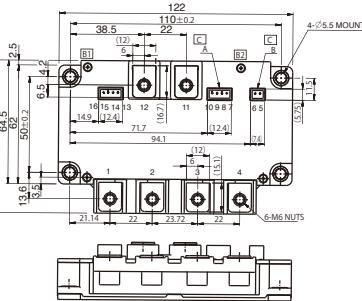
1200V/75A Hybrid/Full SiC-IPM for Industrial Equipment PMH75CL1A120/PMF75CL1A120 600V/75A Full SiC-IPM for PV Applications PMF75B4L1A060



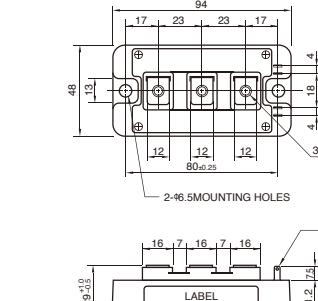
1200V/400A, 1200V/800A Full SiC Power Modules for Industrial Use FMF400BX-24A FMF800DX-24A



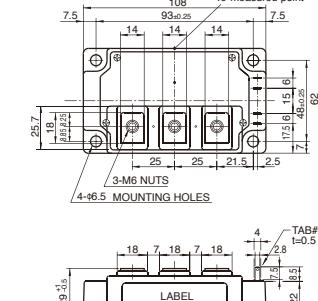
Full SiC Power Modules for Industrial Equipment FMF600DX2-24A FMF800DX2-24A



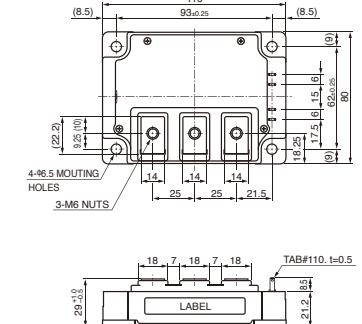
Hybrid SiC Power Modules for High-frequency Switching Applications CMH100DY-24NFH CMH150DY-24NFH



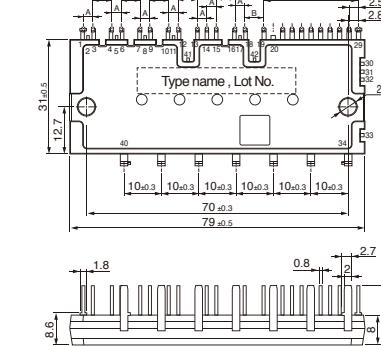
Hybrid SiC Power Modules for High-frequency Switching Applications CMH 200DU-24NFH CMH 300DU-24NFH



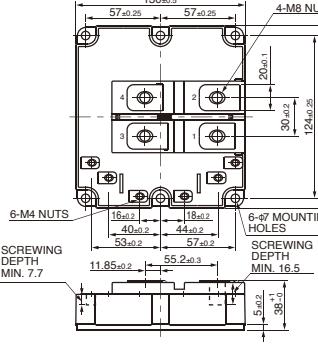
Hybrid SiC Power Modules for High-frequency Switching Applications CMH 400DU-24NFH CMH 600DU-24NFH



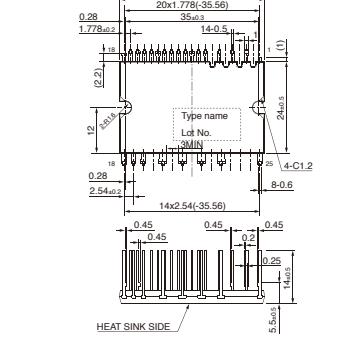
600V/50A Large Hybrid SiC DIPIPM™ for PV Applications PSH50YA2A6



1700V/1200A Hybrid SiC Power Modules for Traction Inverters CMH1200DC-34S



Super-mini Full SiC DIPIPM™ PSF15S92F6-A / PSF25S92F6-A Super-mini Hybrid / Full SiC DIPPFC™ PSH20L91A6-A / PSF20L91A6-A Long



Development of Mitsubishi Electric SiC Power Devices and Power Electronics Equipment Incorporating Them

Mitsubishi Electric began developing SiC as a new material in the early 1990s. Pursuing special characteristics, we succeeded in developing various elemental technologies. In 2010, we commercialized the first air conditioner in the world equipped with a SiC power device. Furthermore, substantial energy-saving effects have been achieved for traction and FA machinery. We will continue to provide competitive SiC power modules with advanced development and achievements from now on.

Contributing to the realization of a low-carbon society and more affluent lifestyles

